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*Indian Standard*

# METHODS FOR PERFORMANCE ASSESSMENT OF ULTRASONIC FLAW DETECTION EQUIPMENT

**भारतीय मानक**

**पराश्रव्यी दोष मालूम करने के उपस्कर की कार्यकारिता मूल्यांकन की पद्धतियां**

UDC 620·179·15·05

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

*January* 1990

**Price Group 5**

Non-Destructive Testing Sectional Committee, SMDC 25

# FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 10 December 1988, after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Structural and Metals Division Council.

This standard has been prepared for the guidance of persons involved in non-destructive ultrasonic testing and will be useful for checking the performance of equipment and the variations in performance arising from ageing, wear and tear, etc.

To simplify methods of checking and to make them directly informative, calibration blocks including those as specified in IS 4904 : 1982 'Calibration blocks for evaluation of ultrasonic flaw detection equipment ( *second revision* )' suitable for use both on site and in laboratory have been recommended in this standard. In certain cases, however, it has been found necessary to recommend blocks which can best be used only in a test room. Some recommendations cover only generic types of choice of dimensions; test material and surface finish being left to contracting parties who will be guided by considerations of practical relevance, such as test ranges and working sensitivity levels.

# *Indian Standard*

# PERFORMANCE ASSESSMENT OF ULTRASONIC FLAW DETECTION EQUIPMENT

## 1 SCOPE

**1.1** This standard deals with methods for checking the overall performance of ultrasonic flaw detection equipment along with the probe.

**1.2** This standard provides practical guidance for evaluation of some of the parameters of ultrasonic flaw detection equipment which strongly influence the integrity of flaw detection and assessment. It may be noted here that while some parameters depend only upon the probes, some others depend only upon flaw detector and the remaining parameters depend both upon the probes and flaw detector.

NOTE — More accurate assessment of the sound field ( or at least a more direct one ) is possible by using laboratory equipment, such as, beam plotters or simple optical ( Schlieren ) visualizer. Such methods are, however, regarded as beyond the scope of this standard.

**1.3** This standard applies to compressional and shear-wave probes used in contact scanning but not to probes used in immersion testing techniques for which more complex checks are required.

**1.4** This standard does not cover general and environmental testing of ultrasonic flaw detection equipment.

## 2 REFERENCES

The Indian Standards listed below are necessary adjuncts to this standard:

| | |
|---|---|
| IS 2417 : 1977 | Glossary of terms relating to ultrasonic testing ( *first revision* ) |
| IS 4904 : 1982 | Calibration blocks for evaluation of ultrasonic flaw detection equipment ( *second revision* ) |

## 3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 2417 : 1977 shall apply.

## 4 LINEARITY OF TIME BASE OF FLAW DETECTOR

**4.1** Linearity of time base depends only upon flaw detector.

### 4.2 Ranges

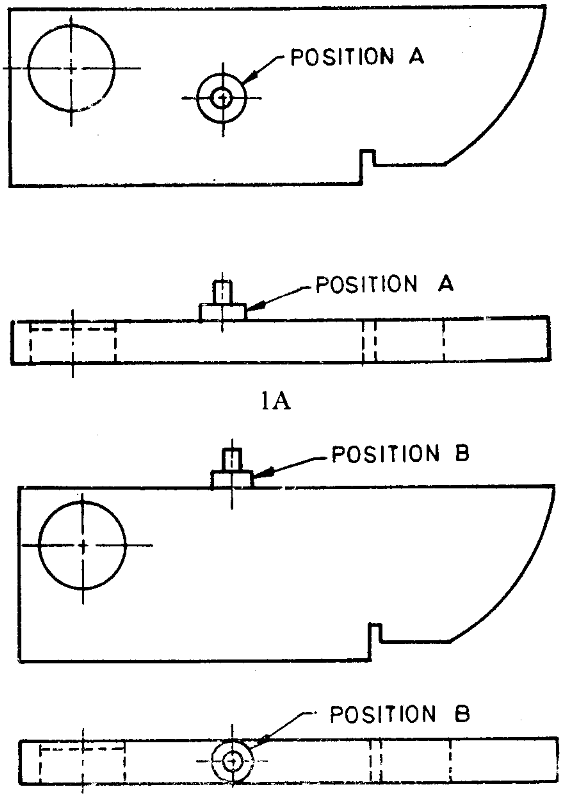
The linearity of time base shall be checked for the complete range.

### 4.3 Selection of Probe

For checking the linearity of time base up to 100 mm, probe of any diameter and frequency may be used. However, for ranges greater than 100 mm, both the diameter and the frequency should be as large as available. This is necessary in order to have smaller beam spread to avoid effects of mode transformation ( for example, side wall echoes ).

### 4.4 Probe Position

For time base ranges up to 100 mm, the probe shall be placed at position *A* and for time base ranges above 100 mm to 500 mm at position *B* on the calibration blocks ( *see* Fig. 1A and 1B ).



1A

1B

FIG. 1 PROBE POSITION FOR CHECKING LINEARITY OF TIME BASE USING CALIBRATION BLOCK

### 4.5 Setting of the Time Base

The time base shall be adjusted in such a way that a multiple echo pattern is displayed. At least two of the bottom echo indications ( generally, the first and the last on the screen ) separated by at least two other indications, shall coincide with the particular scale markings. The intermediate echoes should then line up with appropriate positions on the scale.

### 4.6 Gain Setting

The successive bottom echoes shall be brought to substantially the same amplitude ( that is, greater than half-full scale usable deflection ) when measuring their positions against graticule.

### 4.7 Assessment of Linearity

To assess the linearity of the time base, the intervals between the leading edges of successive bottom echoes shall be measured and their deviation with respect to the graticule recorded.

> "The maximum deviation ( *a max* ) among deviations of the stand-up points for each echo may be recorded and then linearity may be calculated by the following formula:
>
> $$T = \frac{a\ max}{0{\cdot}8\ b} \times 100 \text{ percent}$$
>
> where '*b*' is the full scale of the time base".

The results may be presented graphically by plotting as the abscissa, the echo position corresponding with a linear scale and as the ordinate the positions of the echoes as observed on the screen ( *see* Fig. 2 ).

Deviations from linearity shall be expressed as a percentage of the time base range considered over the full scale reading. Non-linearity of more than ±2 percent to ±1 minor subdivision on the time base scale is not permissible.

## 5. LINEARITY OF AMPLIFICATION OF FLAW DETECTOR

### 5.1 General

Linearity of amplification depends upon the frequency of receiving probe used, setting up of pulse power, grain control and time base range of the flaw detector. It is desirable that the deviation from linearity of amplification be checked for all the frequency ranges and at all the settings of pulse power, gain and time base.

### 5.2 Probe Position

For the time base ranges of 250 mm, the probe shall be positioned at ( Fig. 1A ) on the calibration block and for a range of 500 mm shall be positioned at *B* ( *see* Fig. 1B ). In the first case, ten multiple echoes will be observed and in the second case, five. The multiple echoes are indicated by the indices 1, 2, 3, 4, etc ( *see* Fig. 3 ).

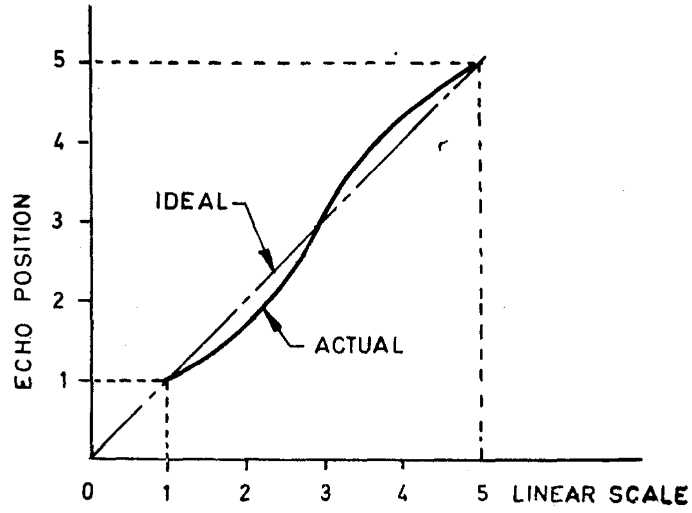


FIG. 2 EXAMPLE OF DIAGRAM SHOWING LINEARITY OF THE TIME BASE

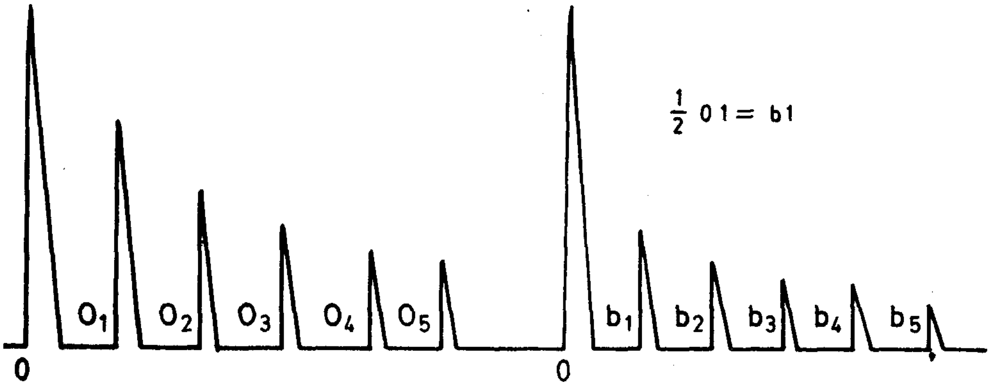


FIG. 3 EXAMPLE OF DIAGRAM FOR CHECKING LINEARITY FOR AMPLIFICATION

### 5.3 Gain Setting

The gain shall first be set up to give the $n$ to echo ( where $n$ is any of the echoes indicated, on full usable scale height or the height specified by the manufacturer ( $a_n$ ). Any control for a suppression of signals below threshold level shall be set to zero. The height in mm of the following bottom echo shall be recorded as $h_1$. The gain shall be reset to obtain the echo at 50 percent of the original scale height and the height of the following bottom echo shall be read as $h_2$.

### 5.4 Assessment of Linearity

The linearity of the equipment shall be assessed by checking:

$$\frac{h_2}{h_1} = 50 \text{ percent}$$

Percentage deviation is expressed as

$$D_v = \frac{h_1 - 2h_2}{h_1} \times 100$$

Generally, deviation of non-linearity of more than ±5 percent is not permissible.

## 6 PENETRATIVE POWER

### 6.1 General

Attention is drawn to the fact that this evaluation can only be used as an indication of maximum penetrative power by direct comparison of different units, that is, instruments and/or probes. However, acceptance based on the penetrating power is subject to mutual agreement between the manufacturer and the user of the ultrasonic equipment/probe system. A definite assessment cannot be obtained using simple methods due to the differences in the manufacture of the plastic insert, influence of temperature on the results obtained, reflection from sides of calibration block, etc.

### 6.2 Probe Position

The probe shall be placed at position $C$ ( *see* Fig. 4 ) on the calibration block given in Fig. 13 using a time base range of 500 mm.

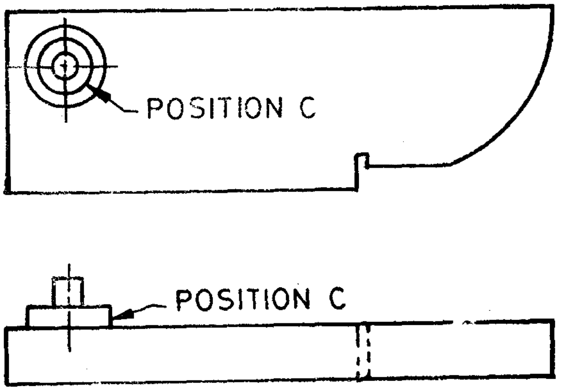


FIG. 4 PROBE POSITION FOR CHECKING RESOLUTION PENETRATIVE POWER

### 6.3 Gain Setting

The controls shall be set to give maximum gain and maximum pulse energy. Any control for suppression of signals below threshold level shall be set to maximum suppression.

### 6.4 Assessment of Penetrative Power

To assess maximum penetrative power, the number of multiple echoes obtained from the bottom of the plastic insert.

In the block and the amplitudes on the echoes shall be determined.

NOTE — An alternate method is through the use of 1·5 mm hole of calibration block given in Fig. 13. The probe is placed as shown in Fig. 5 and its position is adjusted till the echo height is maximum. With reject control and attenuation in amplifier set to zero the gain control is set to get mid-screen echo height. Next, the gain control is set at maximum and the attenuation is introduced in the amplifier till the echo height is again in the middle of the screen.

The amount of attenuation so introduced, known as 'gain reserve', is a measure of penetrative power or overall system gain. Usually, a gain reserve of 35 dB may be accepted. However, this figure depends upon the flaw detector as well as on the probe; with the same probe, some flaw detectors may give higher gain reserve. Also, for critical flaw detection in highly attenuating materials, this figure may be considered low.

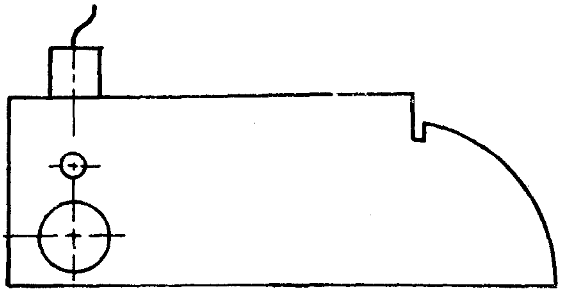


FIG. 5 TEST BLOCK SETTING FOR CHECKING OVERALL SYSTEM GAIN

## 7 RESOLVING POWER

### 7.1 General

This depends upon both the probe and the flaw detector. Axial resolving power only is usually of significance. However, when two reflecting targets lying sideways approximately the same distance from probe are to be detected, lateral resolving power is also to be checked.

### 7.2 Axial Resolving Power

#### 7.2.1 *Probe Position*

The probe shall be placed on the centre line of the calibration block shown in Fig. 1A over the change in radius from one step to the next. Its position is adjusted so that the echoes from the two successive steps are of the same height.

#### 7.2.2 *Gain Setting*

The echoes of two successive steps shall be approximately half screen height.

#### 7.2.3 *Assessment of Resolving Power*

The steps are said to be resolved when their echoes are clearly separated at least up to 6 dB below maximum echo height as shown in Fig. 6.

### 7.3 Lateral Resolving Power

This is evaluated from the angle $\phi$ subtended by the region of maximum intensity ( acoustical axis ) and the line on which intensity drops down by 6 dB. It is then expressed by tan $\phi$.

For normal beam probe, a block as shown in Fig. 13 is used. The probe is first placed to get maximum echo height from the hole and is then shifted sideways till echo height drops by 6 dB. The lateral resolution is then given by tan $\phi$ or by $d/R$, where $d$ is probe shift and $R$ is the distance of hold from the probe.

For angle beam probe, a block as shown in Fig. 14 is used. The target echo is maximized and the probe position is marked preferably on a guide strip. The probe is then shifted successively to the left or to the right until the echo height is dropped by 6 dB. The angular resolution power for the angle beam is then expressed as probe shift $D$ divided by distance $R$.

## 8 PROBE INDEX

### 8.1 General

This depends only upon the probe. Probe index of an angle beam probe can be determined with the help of $A2$ calibration block given in IS 4904 : 1982.

Block given in Fig. 14 provides one test range of 100 mm and block given in Fig. 15 provides two test ranges of 75 and 140 mm. Whichever block is used, it is advisable to position a guide strip, preferably magnetic, on one side face to ensure that the probe's movement is always parallel to the side faces. A convenient size of the guide strip will be 150 mm × 25·3 mm.

The position of the probe index should be ascertainable to within ±1 mm.

### 8.2 Probe Position

The probe is kept on the block such as to get echoes from the curved surfaces of the blocks. The probe is moved till maximum height of echo is achieved.

### 8.3 Gain Setting

It is recommended that rejection control be kept at maximum and pulse energy at about middle position.

### 8.4 Assessment of Probe Index

The point of probe exactly above the centre of the curved surface of block ( marked on the block ) is the probe index.

NOTES

1 It is the first indispensable characteristic which should be determined before any comparisons of beam angle or beam profile are attempted. It may be significantly different than marked on the probe.

2 To meet the cases where the specified procedure or the conditions of the test call for continuous checking on site, the miniature block specified in IS 4904 : 1982 is recommended. This block is 12·5 mm thick and is, therefore, prone to side wall echoes if used with too large a probe.

3 In case of squint in the probe ( *see* 12 ), the use of guided strip is not recommended.

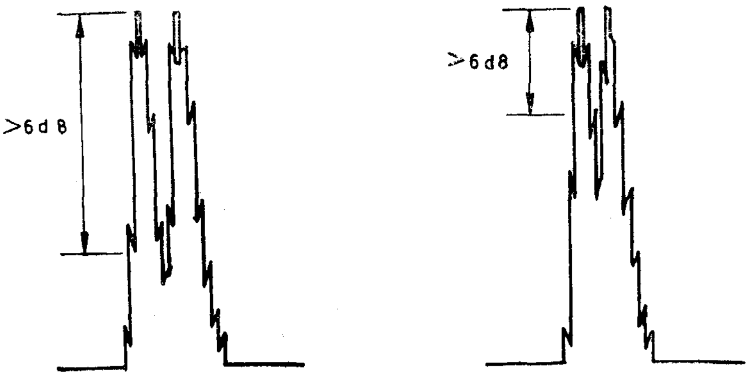
## 9 BEAM ANGLE

### 9.1 General

The beam angle depends only upon the probe. The calibration block ( *see* Fig. 13 ) can be used for the evaluation of angle at which the beam emerges out from the angle beam probe. Miniature block ( *see* IS 4904 : 1982 ) may also be used for this purpose. Miniature block is not recommended for accurate determination of beam angle. This block is, however, quite suitable for detection of drift in the values of angle previously determined.

### 9.2 Probe Position

When block as given in Fig. 13 is used, the probe is placed such that the echoes from either 1·5 mm



6A 3 mm Step Echoes Resolved

6B 3 mm Step Echoes not Resolved

FIG. 6 LINEAR DISPLAY FOR PROBE RESOLUTION

diameter hole or from 50 mm diameter hole or from 50 mm diameter plastic insert are of maximum height. When block as given in Fig. 14 is used, probe is placed such that the echoes from either 1 2 mm diameter hole or from 75 and 140 mm arcs after reflection are of maximum height.

### 9.3 Gain Setting

It is recommended that rejection control be kept at maximum and pulse energy at about middle position.

### 9.4 Assessment of Beam Angle

The angle marked on the block and lying just below the probe index is taken as the probe angle. If probe index falls between two marks, the beam angle may be calculated as shown in Fig. 7. The deviations in beam angle as specified by the manufacturer shall be within ±2°.

NOTE The probe should be moved from the zero degree angle position to increasing angle side. It may otherwise be misleading as a probe of 45° may show maximum height position at about 60° also.

## 10 BEAM PROFILE

### 10.1 General

This depends only upon the probe. The method described below gives only a qualitative assessment of beam profile. For more accurate evaluation, point measurement of the field intensity would be required and shall not be given here. For most purposes of non-destructive testing, the method pescribed here will suffice.

### 10.2 Normal Beam Probe

This block shown in Fig. 14 is to be used. The clock has reference lines marked on its surfaces just above the axis of the hold. The choice of depths of hole depends upon the need of the job. If required, another block with depth 10, 15, 25 and 40 mm may be used.

**10.2.1** *Probe Position*

The probe is first marked at four numbered reference point 90° apart. With twin-crystal probes, it may be necessary to identify the transmitter. Next, the position of the acoustical axis of the beam ( *see* Fig. 8 ) has to be checked by maximizing the echo from the deepest target for all the four reference points. If the maximum echo position does not coincide with the reference line on the face of block ( centre line of target ) within 2 mm, the axis is probably not centrally aligned and has to be checked at other ( intermediate ) reference points ( There will always be two position 180° apart, at which the acoustical axis and target will lie in the same plate ).

**10.2.1.1** With the axis and the echo maximized position $P$ in Fig. 8A, the edge positions of the probe is marked on the block The probe is then drawn back from the target reference line until the signal has dropped to one tenth of its original height ( position $P$ ) and the edge marked again.

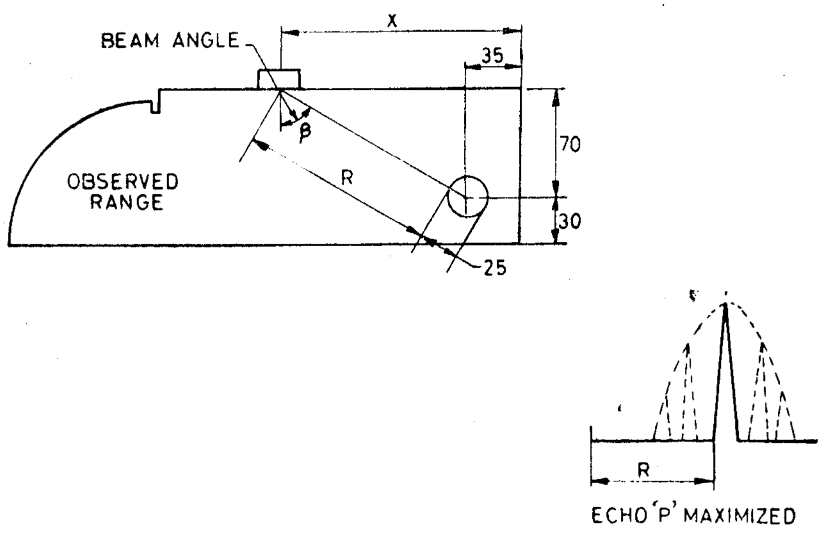
**10.2.2** *Gain Setting*

Any control for suppression of signals below threshold level shall be set to zero.

**10.2.3** *Assessment of Beam Profile*

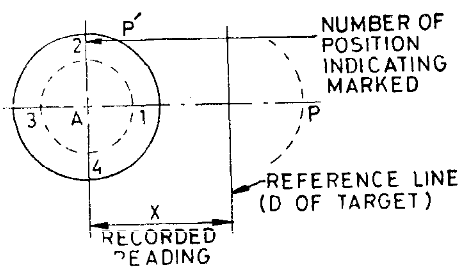
Measurement of the probe shall shift in **10.2.1** gives the half-width of the beam at this level which is plotted as distance $X$ in Fig. 8B.

**10.2.3.1** The probe is rotated through successive intervals of 90° for point 2, 3 and 4 and the procedure repeated. The completed plot for four different depths then gives beam profile as shown in Fig. 8(B).

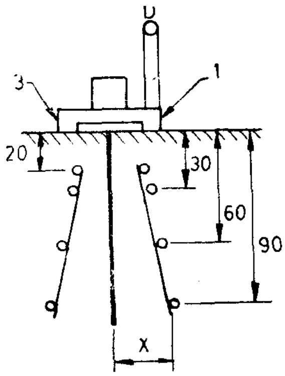


All dimensions in millimetres.

FIG. 7 CALCULATION OF BEAM ANGLE ( ALTERNATIVE TO VISUAL ESTIMATION ) MEASURED


P′
2
3
A
1
4
NUMBER OF POSITION INDICATING MARKED
P
REFERENCE LINE (D OF TARGET)
X
RECORDED READING

8A Probe Positions



8B Beam Profiles

All dimensions in millimetres.

Fig. 8 Probe Positions and Beam Profiles

### 10.3 Angle Beam Probe

**10.3.1** *Vertical Plane*

The calibration block shown in Fig. 15 is for plotting beam profile of angle beam probes.

**10.3.1.1** The block with target holes at different depths and means of measuring probe shift about a fixed reference point is required which, in this case, is usually the probe index. The 10/1 amplitude drop is used, the sequence of operations being shown in Fig. 9.

**10.3.1.2** For the final plot, the reported beam index is taken as the master reference point whilst the axis is drawn through the points indicated by the maximum echo positions. If these do not lie close to the line, the test should be repeated.

**10.3.1.3** A useful cross-check on reproducibility of results can be made by reversing the plotting procedure. To do this, the reputed index is ignored and one edge of the probe shoe is used instead as the reference point for the cross-check. A line drawn through the maximum echo positions should intersect the work surface line at a point 1 mm from the reputed index point whilst the angle measured between the new axis and the vertical through the new index should be within ± 0·5° of the angle originally determined. If the foregoing conditions are not met, it will be necessary to decide which of the two results is to be considered valid for the job concerned, namely, the one based on as given in Fig. 13 block or the one based on very small targets.

**10.3.2** *Horizontal Plant*

The horizontal profile is plotted in the same way as the vertical but using 50 mm face in Fig. 9(B). This procedure involves maximizing the echoes from the tips of target holes and lateral probe traverse to find 10/1 signal drop position.

## 11 OPERATING FREQUENCY

**11.1** For accurate measurement of frequency, electronic instruments, such as, spectrum analyser, have to be used. However, for practical purposes, following method is recommended.

**11.1.1** The maximum echo from 25 mm thickness of the *A*2 block is obtained. The unrectified display is used for this measurement. If the flaw detector does not provide an unrectified display, it shall be obtained by connecting an oscilloscope to the flaw detector amplifier at the point immediately before the signal is rectified. The display of unrectified pulse shall be such that the zero signal level is at mid-screen and the highest amplitude cycle reaches the top or the bottom of the screen. The time scale shall be calibrated to give 5 µs full screen width.

**11.2** The integral number of complete cycles which just lie within the pulse length is counted. The pulse length is measured in time as shown in Fig. 10. The frequency is then obtained by dividing the number of cycles by the time interval of pulse length.

## 12 BEAM ALIGNMENT ( SQUINT )

**12.1** Beam alignment depends only upon the probe.

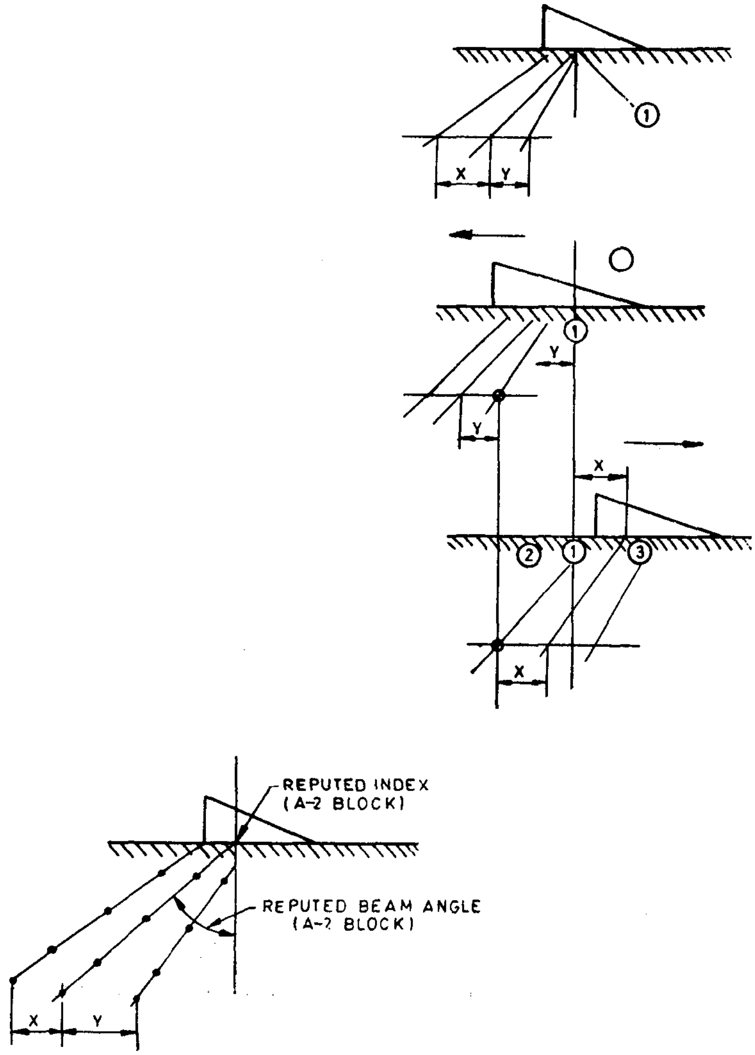


FIG. 9 SEQUENCE OF OPERATIONS FOR CHECKING BEAM PROFILES OF SHEAR WAVE PROBES

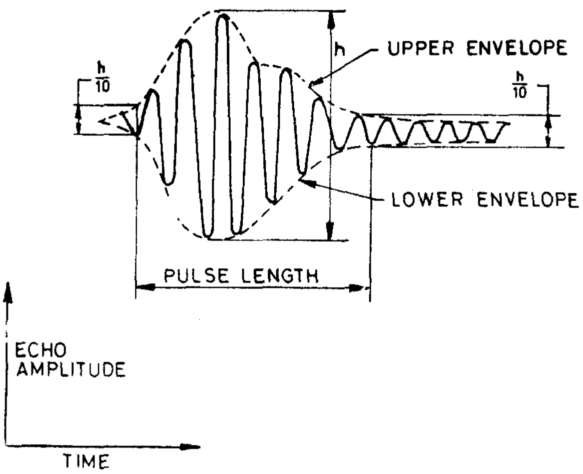


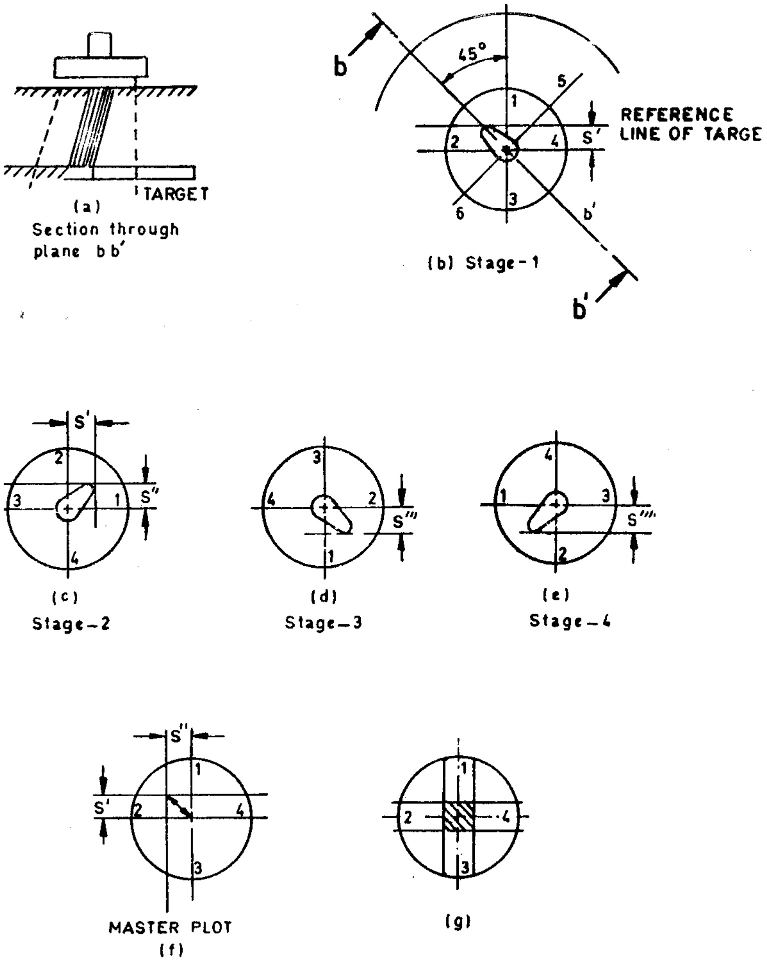
FIG. 10 DEFINITIONS OF PULSE LENGTH AND PULSE ENVELOPES

### 12.2 Normal Beam Probe

The calibration block shown in Fig. 14 is used and the procedure is essentially the same as for plotting the beam profile ( *see* **10** ).

**12.2.1** If, when maximizing a target echo, the relevant probe reference line does not coincide with the target reference line marked on the surface of the calibration block, the probe axis is out of alignment and the extent of the same has to be ascertained. It is also called as 'shifts' of the probes.

**12.2.2** In Fig. 11(a) and (b), it is assumed that the beam is reflected in 45° direction along the line *b—b'*. At stage 1 ( Fig. 11B ), the maximum signal will be received only when the probe has been drawn back from the target reference line ( engraved on the block ) through the shift distance [ *see* Fig. 11 (c), (d) and (e) ], the point at which the beam axis strikes the target lies ahead of the 2-4 line and *s* in this position on the master plot [ Fig. 11(f) and (g) ].



(a) Section through plane b b'

(b) Stage-1

(c) Stage-2

(d) Stage-3

(e) Stage-4

MASTER PLOT (f)

(g)

FIG. 11 ALIGNMENT OF BEAM COMPRESSIONAL WAVES

# ANNEX A

## CALIBRATION BLOCKS FOR PERFORMANCE TESTING OF ULTRASONIC FLAW DETECTION EQUIPMENT

### A-1 PHYSICAL PROPERTIES

**A-1.1 Dimensions**

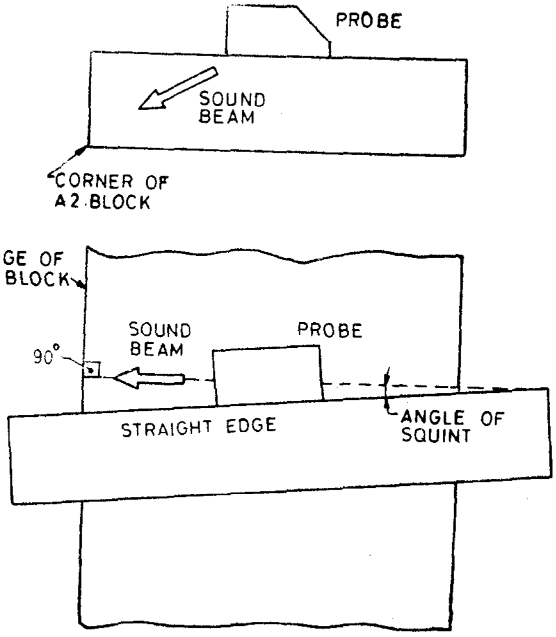
The dimensions of calibration block shall conform to those given in respective figures.

**A-1.2 Tolerances**

Wherever practicable, the limits on dimensions shall be held to ± 0·10 mm.

**A-1.3 Material**

Block shall be manufactured from low carbon alloy ferritic steel, open hearth killed, normalized to produce, a fine-grained structure and homogeneous throughout. The material shall be free from internal flaws.



PROBE IS TURNED TO GIVE A MAXIMUM SIGNAL

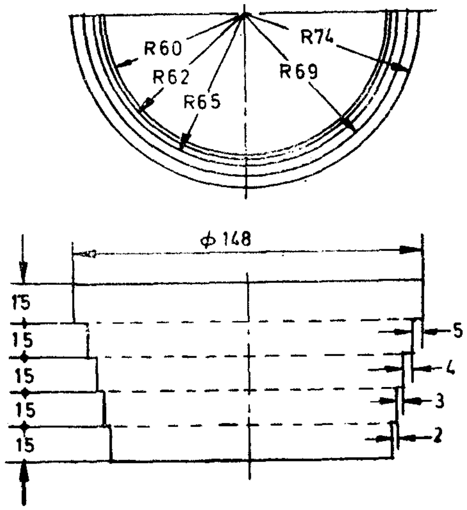
FIG. 12 MEASURING SQUINT ON THE CALIBRATION BLOCK

**A-1.4 Surface Finish**

The surfaces of the block shall be finished to $R_a$ value not greater than 0·8 μm.

### A-2 RESOLUTION BLOCK

This block shall have the dimensions shown in Fig. 13.



All dimensions in millimetres.

FIG. 13 CALIBRATION BLOCK FOR CHECKING RESOLUTION

### A-3 BEAM PROFILE BLOCK *C*

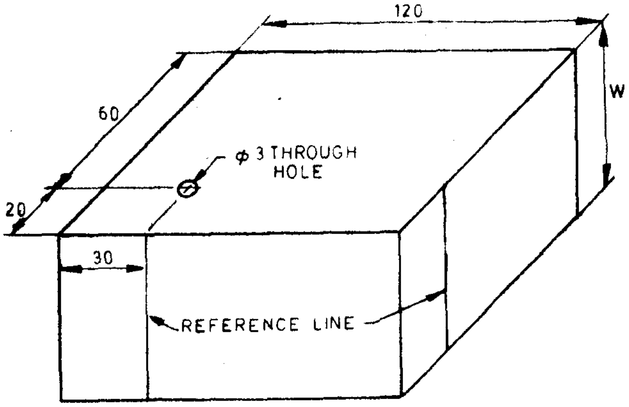
The block shall have dimensions shown in Fig. 14. The width *W* shall be so chosen that it would be two times greater than the diameter of the probe.

### A-4 BEAM PROFILE BLOCK *S*

The block shall have dimensions shown in Fig. 15.

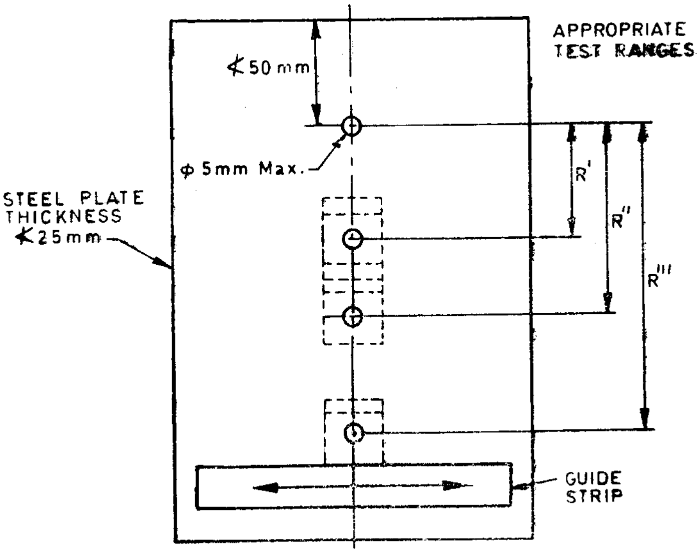
### A-5 LOW BLOCK

This block shall have dimensions shown in Fig. 16.



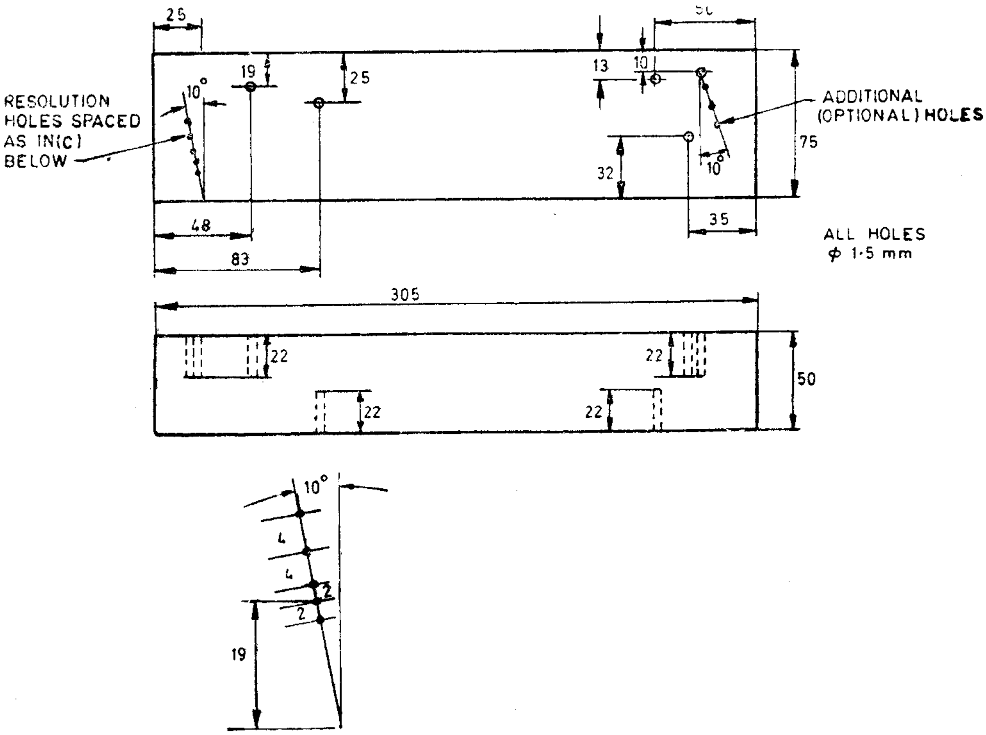
All dimensions in millimetres.

FIG. 14 BEAM PROFILE BLOCK *C*



All dimensions in millimetres.

FIG. 15 BEAM PROFILE BLOCK *S*



All dimensions in millimetres.

FIG. 16 WELDING INSTITUTE ( IOW ) BLOCK FOR CHECKING BEAM PROFILE AND RESOLUTION

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Doc : No. SMDC 25 ( 2859 )

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Printed at Printograph, Delhi, India